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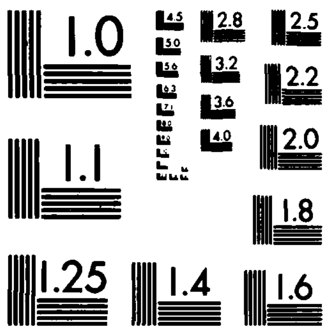

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BALANCING ACCESSION AND RETENTION: COST AND PRODUCTIVITY TRADEOFFS

Ellen Balis

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BALANCING ACCESSION AND RETENTION:
COST AND PRODUCTIVITY TRADEOFFS

In this paper, we use a rating-specific model that incorporates both cost and productivity data to find the most efficient balance of accession and retention. We find that increasing retention by raising Zone A bonus payments is cost-effective. Additional monies budgeted for bonus payments and second-term pay are more than offset by reductions in recruiting and training costs and first-term pay. Alternatively, holding costs at current levels, ~~we find~~ that increasing retention leads to a more productive force.

THEORETICAL FRAMEWORK

Our model is used at the rating level to minimize costs given an effectiveness level and to maximize productivity given a budget constraint. The model is formulated in two ways. In the simplified version, all reenlistment eligibles either reenlist or leave at the end of the first term. In the more complex version, reenlistment eligibles also have the option to extend and then either reenlist or leave at the end of the extension period.

Simplified Model

The cost of a cohort in the simplified model is defined as $C = \gamma_1 X + M\delta RX + \gamma_2 RX$, where

γ_1 = the present discounted value of the cost per eligible over the first term

γ_2 = the present discounted value of the cost per person starting the second-term over years of service 5 through 8

M = the annualized value of the bonus payment

δ = a discount factor

X = the number of reenlistment eligibles in the rating at the end of the first term

and R = the reenlistment rate which is a function of M.

We specify R using the CNA Annualized Cost of Leaving (ACOL) model as a logistic function [1]. The derivative of R with respect to M is equal to $R(1-R)\beta$, where β is the coefficient of responsiveness of reenlistment rates to pay changes.

Productivity, similarly, is defined as $F = \Theta_1 X + \Theta_2 RX$ where

Θ_1 = the productivity per eligible over the first term

and Θ_2 = the productivity per person starting their second term over that term.

To find the optimal solution, we set up the Lagrangian $L = \gamma_1 X + M\delta RX + \gamma_2 RX + \lambda(F - \Theta_1 X - \Theta_2 RX)$, where X and M are the Navy's decision variables. Knowing the probability of reaching eligibility given assignment to a rating (we assume assignment occurs before recruit training) and the number of eligibles, X, we can determine the required accessions.

We then derive the three first-order conditions for optimality:

$$(1) \quad \frac{\partial L}{\partial X} = 0 = \gamma_1 + M\delta R + \gamma_2 R + \lambda(-\theta_1 - \theta_2 R)$$

$$(2) \quad \frac{\partial L}{\partial M} = 0 = \delta RX + M\delta XR(1-R)\beta + \gamma_2 XR(1-R)\beta + \lambda(-\theta_2 XR(1-R)\beta)$$

$$(3) \quad \frac{\partial L}{\partial \lambda} = 0 = F - \theta_1 X - \theta_2 RX \ .$$

By solving equation 2 for λ and substituting into equation 1, we obtain the following expression for the optimal annualized bonus payment.

$$(4) \quad 0 = \theta_2\gamma_1 - \theta_1\gamma_2 - \delta\left[\frac{R\theta_2+\theta_1}{(1-R)\beta} + M\theta_1\right].$$

It can be shown in this case that whenever these first-order conditions are met, the solution is a minimum.

Equation 4 gives an optimal bonus payment level depende on the costs and effectiveness of first- and second-termers and the responsiveness of first-term reenlistments to pay. Increases in first-term costs or decreases in first-term effectiveness lead to increases in the optimal bonus level. In contrast, optimal bonus levels decrease with increases in second-term costs and, at current reenlistment rates, decreases in second-term effectiveness. Optimal bonus levels also decrease with increases in the responsiveness of reenlistment rates to pay and the base reenlistment rate. Appendix A mathematically defines these relationships.

Model with Extenders Added

We next complicate the model by including extensions. Extenders face a second decision at the end of their extension and can then either reenlist or leave the Navy.

In this model, costs are defined as

$$C = \gamma_1 X + M\delta_1 R_1 X + \gamma_2(R_1+E_1)X + M\delta_2 R_2 E_1 X + \gamma_3(R_1+E_1 R_2)X$$

where

γ_1 = present discounted value of the cost per eligible through the first term

γ_2 = present discounted value of the cost per second termer from the start of year 5 to the end of the average extension period

γ_3 = present discounted value of the cost per second termer from the end of the average extension period to the end of year 8

M = the annualized bonus payment

δ_1 = a discount factor

δ_2 = a discount factor

X = the number of reenlistment eligibles in the rating at the end of the first term

R_1 = the initial reenlistment rate which is a function of M

E_1 = the initial extension rate which is a function of M

R_2 = the reenlistment rate for those who initially extend which is again a function of M.

We again specify E and R as logistic functions of M using ACOL. The derivative of each R with respect to M is still $R(1-R)\beta$, while the derivative of E with respect to M is $-RE\beta$.

Likewise, productivity is defined as $F = \Theta_1 X + \Theta_2(R_1 + E_1)X + \Theta_3(R_1 + E_1R_2)X$

where

Θ_1 = the productivity per eligible over the first term

Θ_2 = the productivity per second termer from the start of the second term to the end of the average extension period

and Θ_3 = the productivity per second termer from the end of the average extension period to the end of year 8.

Again, we set up the Lagrangian

$$L = \gamma_1 X + M\delta_1 R_1 X + \gamma_2(R_1+E_1)X + M\delta_2 R_2 E_1 X + \gamma_3(R_1+E_1R_2)X + \lambda(F - \Theta_1 X - \Theta_2(R_1+E_1)X - \Theta_3(R_1+E_1R_2)X)$$

where X and M are the Navy's decision variables.

By setting up the first order conditions for optimality, we are able to implicitly define the optimal bonus level. Appendix B derives this equation. Again, the optimal bonus level is dependent on the cost and productivity of first and second termers and the responsiveness of reenlistments and extensions to pay.

CALCULATION OF PARAMETERS

Table 1 shows the eight rating groups for which cost and productivity data was available. To empirically estimate optimal bonus and accession levels for each group, we calculate the required inputs for the model. This section details the derivation of each parameter. Appendix C presents the equations used to calculate each element. Appendix D lists all basic data used in the calculations.

TABLE 1

RATING GROUPS

1. DT, HM
2. AK, DK, SH, SK, MS
3. EM, IC
4. MM
5. ET
6. AD, AM, AS
7. AE, AQ, AT, AX, TD
8. RM

Cost of First Termers

The cost per eligible was calculated using the methodology outlined in [2]. Costs include recruiting, AFEES processing, recruit training, specialized A-school training and regular military compensation (RMC) for the first four years of service. Each cost is adjusted for attrition that occurs later in the term. An adjustment is made so that recruiting and recruit training costs are not included for those who fail A-school training but do not leave the Navy. All costs are calculated in present discounted value using a 10 percent discount rate.

Costs for AFEES processing and training are taken from the Navy Comprehensive Compensation and Supply Study (NACCS) [3] but are adjusted for inflation and expressed in 1982 dollars. RMC tables for 1982 were used along with pay grade distributions from the September 1980 Enlisted Master Record (EMR) to calculate annual pay levels. NACCS provided estimates of all necessary attrition rates. All data from NACCS is based on non-prior service males who enter the Navy with an initial obligation of four years.

Table 2 lists two sets of first-term costs by rating group. The first set does not include recruiting costs. This tends to understate first-term costs and will therefore provide low estimates of the optimal bonus.

The second column of table 2 includes marginal recruiting costs consistent with current levels of accessions. This recruiting cost is calculated using the exponential function derived in [3]. Since the function is exponential, marginal recruiting costs increase with the number of recruits. Since increasing the reenlistment rate reduces the number of required recruits, using a cost associated with current accession levels tends to overstate costs and thus overstate the optimal bonus.

The two bonus levels we derive will then give upper and lower bounds to the actual optimal bonus level. It was not possible to calculate a more exact value, because the recruiting function is based on an aggregate model and can not be used at the rating level.

TABLE 2

COSTS PER ELIGIBLE

Rating	No recruiting costs included	Recruiting cost of $4304 included
1	$48,024	$54,409
2	45,028	51,266
3	49,227	56,773
4	48,370	54,540
5	58,152	66,063
6	45,637	52,085
7	51,561	58,515
8	48,938	55,394

Cost of Second Termers

Cost per second termer is RMC for years 5 through 8 adjusted for attrition. It is calculated in present discounted value using a 10 percent discount rate.

Attrition rates for each year of the second term were calculated by comparing the September 1979 and September 1980 EMRs. RMC tables for 1982 and pay grade distributions, calculated using the September 1980 EMR, were used to determine pay levels for each year and rating.

Table 3 shows the cost per person who begins the second term through that term for each rating group. Differences across rating groups are a result of differences in the average paygrade achieved.

TABLE 3

COST PER SECOND TERMER

Rating	Cost
1	$22,254
2	22,208
3	22,183
4	22,170
5	22,004
6	22,294
7	22,194
8	22,163

Productivity of First-Term Personnel

The productivity of first-term personnel is calculated using results of recent work done at CNA [4]. It used RAND's Enlisted Utilization Survey (EUS), which gives supervisor's productivity ratings of personnel at various points during the first four years at their initial duty station relative to the average four-year specialist in the same rating. From this data, productivity curves were calculated to show how effectiveness increases over time. By integrating the equations, dividing by the average productivity of a four-year specialist, and adjusting for attrition, we obtain an estimate of the productivity per eligible over the first term relative to that of a four-year specialist. Table 4 presents estirates of productivity per eligible for each of our rating groups.*

TABLE 4

PRODUCTIVITY OVER THE FIRST TERM
(Relative to the Average Four-Year Specialist)

Rating	Relative productivity
1	.7456
2	.6823
3	.6011
4	.5924
5	.4723
6	.6450
7	.5352
8	.6013

* The EUS data covers the DT, HM, MS, EM, MM, ET, AD, AE, and RM ratings. We assume that all the ratings in each of our groups have the same productivity profile as the rating included in the EUS.

Productivity of Second-Term Personnel

For estimating second term productivity we used the EUS data for the period from the start of the 5th year of service until productivity reaches the level of an individual who has been at a duty station for 4 years. We assume that effectiveness remains at this level for the rest of the second term. Again, we integrate the productivity curves, adjust for attrition, and divide by the average productivity of the four year specialist. Table 5 presents our estimates of productivity per person through the second term.

TABLE 5

PRODUCTIVITY PER SECOND TERMER
(Relative to the Average Four-Year Specialist)

Rating	Relative productivity
1	.9559
2	.9559
3	.9559
4	.9559
5	.9476
6	.9559
7	.9559
8	.9490

The assumption of constant productivity after 48 months at a duty station is conservative. At observed reenlistment rates, any increased productivity in the second term would lead to increases in optimal bonus levels.

Reenlistment Behavior

We use the ACOL model to predict reenlistment and extension behavior. CNA estimates of the responsiveness to pay [1] are incorporated into our model after two adjustments. First, we account for changes in the price level from 1974, the base year of the estimates, to 1982, the base year for our analysis. Secondly, we adjust these coefficients which were estimated using a probit model for use in our logistic functional form [5]. Appendix E shows our specification of the re-enlistment decision equations.

For our simple model, using these slope coefficients involves two assumptions: that all individuals in a rating face the same civilian pay, and all influences on reenlistment behavior other than pay, such as civilian unemployment rates, are constant throughout the projection period. We find a base reenlistment rate by comparing the September 1979 and September 1980 EMR. Any reenlistment eligible with an EAOS change of 36 months or more is considered a reenlistee. We can then calculate the intercept coefficient required for using the model for projection.

To use the slope coefficients in our model that includes extenders, a third assumption is required. For the coefficients to be unbiased in this case, increases in reenlistees must come proportionally from the extender and leaver populations. Again, we use the EMR to find a base reenlistment and extension rate for those at their first-reenlistment decision. Also, we find the reenlistment rate for those who initially extend their first term. The required intercept coefficients are then calculated for both the original reenlistment decision and post-extension decision equations.

We determine the average length of an extension by comparing EAOS dates on the EMRs. The average change is determined for those whose service obligation increases from 1 to 35 months.

When calculating bonus payments, we assume that the period of reenlistment is four years. We express the bonus in annualized dollars by finding the annual payment over the four years of the second term that is equal in present discounted value to the lump sum bonus. Again, we use a 10 percent discount rate.

EMPIRICAL RESULTS

Simple Model

We first solve for the optimal solutions in the simplified model. We use the Newton-Raphson method of successive approximation to find the optimal bonus levels for each rating group. Table 6 shows the two sets of optimal bonus levels that correspond to our two sets of first-term costs.

TABLE 6

OPTIMAL BONUS MULTIPLES

Rating	Current (1981) multiple	Optimal level when no recruiting cost	Optimal level when current marginal recruiting cost
1	0	8.3	9.5
2	1.1	7.0	8.0
3	2.7	12.5	14.5
4	6.0	11.1	12.7
5	6.0	15.7	16.7
6	0	7.9	9.2
7	1.4	11.8	12.9
8	0	10.0	11.5

Optimal bonus levels range from 7 to 17. For each of the rating groups, the optimal bonus multiple is above current levels and is, in fact, above the current legal maximum of 6. Although there are interaction effects, we can see that ratings with high first-term costs and low first-term productivity tend to have higher optimal bonus levels. We should note that bonus multiples at this level are well above the range of observed values on which the parameters were calculated. Projections of the effects of multiples at these levels are not precise.

Given the optimal bonus levels, we calculate the number of accessions required to meet the effectiveness constraint. Tables 7 and 8 present the size of the required cohort, the cost associated with the set of policies, and the percent of savings relative to current policy.

Appendix F presents additional information about changes resulting from these policies.

Under optimal policies, required accession levels drop from 17 to 44 percent depending on the rating and cost assumption. Total personnel in the first eight years of service, however, will only decline by 8 to 23 percent since the reduction in accessions and first termers is achieved by increasing the number of second termers. The new force structure results in savings of from 2 to 18 percent. Increases in bonus payments and second-term pay are more than offset by decreases in training costs and first-term pay.

Tables 9 and 10 present results when costs are constrained at current levels and effectiveness can rise. This is the dual to our original problem. Since it is unaffected by scale factors, the optimal bonus level along with the force structure it implies is the same as in the effectiveness constrained case. The tables show that productivity gains vary from 2 to 22 percent, again, depending on the rating and the recruiting cost assumption used. Thus at current costs, the Navy can achieve a more productive force.

TABLE 7

OPTIMAL POLICIES WITH NO RECRUITING COSTS - EFFECTIVENESS CONSTRAINED

Rating	Current cohort size	Current costs (in millions)	Optimal cohort size	Cost of optimal policies (in millions)	Percent savings
1	2503	84.1	1727	76.9	8.6
2	3609	138.2	2496	126.8	8.2
3	1691	57.7	1214	53.7	6.9
4	2190	91.0	1813	88.8	2.4
5	550	11.7	325	10.0	14.5
6	4553	157.9	3169	144.7	8.4
7	2825	75.7	1661	64.2	15.2
8	1763	62.9	1237	57.6	8.4

TABLE 8

OPTIMAL POLICIES WITH CURRENT RECRUITING COST - EFFECTIVENESS CONSTRAINED

Rating	Current cohort size	Current costs (in millions)	Optimal cohort size	Cost of optimal policies (in millions)	Percent savings
1	2503	94.7	1631	84.0	11.3
2	3609	155.3	2375	138.3	10.9
3	1691	65.8	1127	59.4	9.7
4	2190	100.7	1708	96.6	4.1
5	550	13.1	313	10.8	17.6
6	4553	178.4	2992	158.6	11.1
7	2825	85.1	1585	69.6	18.2
8	1763	70.6	1168	62.9	10.9

TABLE 9

OPTIMAL POLICIES WITH NO RECRUITING COSTS - COSTS CONSTRAINED

Rating	Current cohort size	Current productivity	Optimal cohort size	Productivity with optimal policies	Percent productivity increase
1	2503	1223	1889	1338	9.4
2	3609	2112	2721	2302	9.0
3	1691	677	1302	726	7.2
4	2190	1151	1856	1179	2.4
5	550	104	381	122	17.3
6	4553	2205	3458	2406	9.1
7	2825	794	1959	936	17.9
8	1763	764	1348	833	9.0

TABLE 10

OPTIMAL POLICIES WITH CURRENT MARGINAL RECRUITING COST - COSTS CONSTRAINED

Rating	Current cohort size	Current productivity	Optimal cohort size	Productivity with optimal policies	Percent productivity increase
1	2503	1223	1839	1379	12.8
2	3609	2112	2668	2371	12.3
3	1691	677	1248	750	10.8
4	2190	1151	1780	1200	4.3
5	550	104	379	127	22.1
6	4553	2205	3366	2481	12.5
7	2825	794	1939	971	22.3
8	1763	764	1310	857	12.2

Model with Extenders

Now we turn to the model that includes extenders. For both second-term cost and productivity estimates, we determine what percentage is applicable to the period from the start of the second term to the end of the average extension period. This provides the separate parameters needed for this model.

Using the Newton-Raphson method, we approximately solve for the optimal bonus levels. Table 11 shows the solutions for each of the cost assumptions. Bonus levels are virtually identical to those in the simple model. Again, projections at these levels are not precise, but we can say that optimal bonuses are above current levels.

TABLE 11

OPTIMAL BONUS MULTIPLES

Rating	Current (1981) multiple	Optimal level when no recruiting cost	Optimal level when current recruiting cost
1	0	7.9	9.2
2	1.1	7.0	8.0
3	2.7	12.3	14.6
4	6.0	11.1	12.8
5	6.0	15.1	16.3
6	0	7.5	9.0
7	1.4	11.9	13.0
8	0	9.4	11.1

Tables 12 and 13 show the required accessions with the optimal bonus levels, the cost of these policies, and the savings relative to current policy. Appendix F contains additional information about the force structure under optimal policies.

Increases in reenlistment rates resulting from higher bonus payments allow accession levels to decline by 17 to 41 percent depending on rating and cost assumption. The corresponding decline in overall personnel in the first eight years of service is from 8 to 22 percent. The resulting force structure is very similar to the optimal policy solution from the simple model and, here, yields 2 to 16 percent savings. Again, increases in bonuses and second term costs are more than offset by reductions in first term costs.

TABLE 12

OPTIMAL POLICIES WITH NO RECRUITING COST - EFFECTIVENESS CONSTRAINED

Rating	Current cohort size	Current costs (in millions)	Optimal cohort size	Cost of optimal policies (in millions)	Percent saving
1	2503	86.3	1866	80.8	6.4
2	3609	139.6	2564	129.3	7.4
3	1691	57.7	1243	54.0	6.4
4	2190	90.7	1818	88.5	2.4
5	550	11.9	350	10.4	12.6
6	4553	160.9	3370	150.3	6.6
7	2825	76.6	1733	66.5	13.2
8	1763	64.0	1320	59.9	6.4

TABLE 13

OPTIMAL POLICIES WITH CURRENT RECRUITING COST -
EFFECTIVENESS CONSTRAINED

Rating	Current cohort size	Current costs (in millions)	Optimal cohort size	Cost of optimal policies (in millions)	Percent saving
1	2503	96.9	1756	88.5	8.7
2	3609	156.7	2434	141.1	10.0
3	1691	65.8	1145	59.7	9.3
4	2190	100.4	1707	96.3	4.1
5	550	13.2	334	11.3	14.4
6	4553	181.5	3167	165.0	9.1
7	2825	86.0	1654	72.1	16.2
8	1763	71.8	1244	65.5	8.8

Tables 14 and 15 present results for the dual problem for this model. When costs are constrained at current levels, optimal retention and accession policies lead to between 2 and 19 percent increases in productivity.

TABLE 14

OPTIMAL POLICIES WITH NO RECRUITING COSTS -
COSTS CONSTRAINED

Rating	Current cohort size	Current productivity	Optimal cohort size	Productivity with optimal policies	% Productivity increase
1	2503	1297	1992	1384	6.7
2	3609	2156	2768	2328	8.0
3	1691	678	1327	724	6.8
4	2190	1145	1862	1173	2.4
5	550	110	396	124	12.7
6	4553	2305	3609	2469	7.1
7	2825	824	1996	949	15.2
8	1763	801	1410	856	6.9

TABLE 15

OPTIMAL POLICIES WITH CURRENT RECRUITING COST -
COSTS CONSTRAINED

Rating	Current cohort size	Current productivity	Optimal cohort size	Productivity with optimal policies	% Productivity increase
1	2503	1297	1923	1420	9.5
2	3609	2156	2703	2394	11.0
3	1691	678	1263	747	10.2
4	2190	1145	1780	1194	4.3
5	550	110	390	128	16.4
6	4553	2305	3483	2536	10.0
7	2825	824	1972	982	19.2
8	1763	801	1362	877	9.5

Savings and increases in productivity are slightly less than in the simple model. However, the model with extenders included still points toward policies of increasing retention.

FURTHER WORK REQUIRED

The results presented here clearly provide support for increases in reenlistment bonus payments. However, there are several areas where further research would improve them.

First, we ignore several potential effects of first term reenlistment bonuses. Some work has been done which suggests that increases in Zone A bonus payments will lead to reductions in reenlistment rates at the end of the second term [6]. This effect has not, however, been estimated at the rating level. Although to get the same manpower at the start of the third term we can have a lower second term reenlistment rate because of the increase in the number of second termers, we do not know the relative impact of the two effects. It is possible that the inclusion of the lagged bonus effect would lead to lower optimal bonus levels.

Zone A bonus payments may also lead to increases in the average quality of reenlistees. Research on this effect and the corresponding change in average second term productivity could also provide useful information. If second term effectiveness was found to increase with bonus payments, our optimal bonus levels would tend to increase.

Second, we do not consider formal training costs beyond A-school. Our costs are understated for ratings for which more advanced C-schools are usually attended. Developing cost estimates for C-schools would enhance our estimates of the relative costs of first and second termers.

Third, we assumed that productivity remains constant after the fourth year at a duty station. Research on actual productivity changes in the second term could provide new estimates that would tend to raise optimal bonus levels.

CONCLUSION

Our findings on costs and personnel productivity by rating support policies of increased retention coupled with reduced accessions. The optimal bonus payment for all rating groups considered is above the legal limit. Inceases in overall second term pay, which in our model has the same impact as increases in bonus payments, would equivalently be more efficient than current policy. The Navy could either realize substantial savings while being equally productive, or gain effectiveness without cost increases by following this type of policy.

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APPENDIX A

THE DETERMINANTS OF THE OPTIMAL BONUS PAYMENT USING OUR SIMPLE MODEL

The optimal bonus payment is defined in the text by the following equation:

$$(1) \quad 0 = \theta_2\gamma_1 - \theta_1\gamma_2 - \delta\left[\frac{R\theta_2+\theta_1}{(1-R)\beta} + M\theta_1\right] .$$

Thus, the optimal payment depends on the costs and effectiveness of first and second termers and the responsiveness of first-term reenlistments to pay. By using equation (1) to take the derivative of it with respect to each of these parameters, we can show how the optimal bonus payment changes with changes in each of them.

Changes in Optimal Bonus Levels with Cost Changes

We first examine the relationship between costs of first and second termers and the optimal bonus payment. Using equation 1, we find that

$$\frac{\partial M}{\partial \gamma_1} = \frac{\theta_2(1-R)}{\delta(R\theta_2+\theta_1)} .$$

Since all the parameters are positive and the reenlistment rate must be less than 1, this derivative is clearly positive. Thus, the higher the cost per eligible, the higher the optimal bonus payment.

On the other hand, we find that

$$\frac{\partial M}{\partial \gamma_2} = - \frac{\theta_1(1-R)}{\delta(R\theta_2+\theta_1)}$$

which is clearly negative. Therefore, the higher the cost per person in the second term, the lower the optimal bonus level.

<u>Changes in Optimal Bonus Levels with Reenlistment Behavior Changes</u>

We use the ACOL Model to predict reenlistment behavior. The exact specification is presented in appendix E. In addition to an annualized pay stream which includes both bonus payments and regular military compensation (RMC), reenlistment rates depend on a base reenlistment rate or "taste for the rating," α_R, and on the responsiveness of changes in reenlistment rates to changes in pay, β.

Using equation 1, we find that

$$\frac{\partial M}{\partial \alpha_R} = \frac{R(\theta_2 + \theta_1)}{-\beta(R\theta_2+\theta_1)} .$$

This derivative is clearly negative. Increases in the base reenlistment rate, therefore, imply decreases in the optimal bonus payment.

Similarly we find that

$$\frac{\partial M}{\partial \beta} = \frac{\beta R(\Theta_2+\Theta_1)(RMC+M) - \Theta_2 R - \Theta_1}{-\beta^2(R\Theta_2 + \Theta_1)}$$

This will be negative if $\frac{\Theta_2}{\Theta_1} > -\left(\frac{\beta R(RMC+M) - 1}{\beta R(RMC+M) - R}\right)$. The right hand side of the inequality is always less than 1, since $R < 1$. The left hand side of the inequality is the ratio of the productivity of second termers to the productivity of first termers, which by observation is greater than one. Therefore, $\frac{\partial M}{\partial \beta}$ is negative and the more responsive the reenlistment rate is to pay, the lower is the optimal bonus level.

Changes in Optimal Bonus Level with Productivity Changes

We last examine the relationship between optimal bonus levels and the productivity of first and second termers. Again using equation 4, we find that $\frac{\partial M}{\partial \Theta_1} = \frac{(\gamma_2+\delta M)(1-R) + \frac{\delta}{\beta}}{-\delta(R\Theta_2+\Theta_1)}$. This derivative is clearly negative. As the productivity of first termers inceases, the optimal bonus level decreases.

Similarly, we find that $\frac{\partial M}{\partial \Theta_2} = \frac{\gamma_1(1-R) - \frac{\delta R}{\beta}}{\delta(R\Theta_2+\Theta_1)}$. This derivative cannot be unambiguously signed. It is positive if $\gamma_1(1-R) > \frac{\delta R}{\beta}$ or $R < \frac{\gamma_1}{\frac{\delta}{\beta} + \gamma_1}$. This holds true for all observed values of the parameters. Thus, at current bonus levels, increases in second term productivity will lead to an increased optimal bonus level. However, at very high reenlistment rates or low first term costs relative to $\frac{\delta}{\beta}$ this derivative can in fact be negative. Then, increases in the effectiveness of second termers can lead to decreases in the optimal bonus level.

APPENDIX B

EQUATION FOR THE OPTIMAL BONUS PAYMENT IN THE MODEL WITH EXTENDERS

In our model with extenders added we set up the Lagrangian

$$L = \gamma_1 + M\delta_1 R_1 X + \gamma_2(R_1+E_1)X + M\delta_2 R_2 E_1 X + \gamma_3(R_1+E_1R_2)X$$
$$+ \lambda(F - \Theta_1 X - \Theta_2(R_1+E_1)X - \Theta_3(R_1+E_1R_2)X)$$

where X and M are the Navy's decision variables.

The three first-order conditions for optimality are now

$$(1) \quad \frac{\partial L}{\partial X} = 0 = \gamma_1 + M\delta_1 R_1 + \gamma_2(R_1+E_1) + M\delta_2 R_2 E_1 + \gamma_3(R_1+E_1R_2)$$
$$+ \lambda(-\Theta_1 - \Theta_2(R_1+E_1) - \Theta_3(R_1+R_2E_1))$$

$$(2) \quad \frac{\partial L}{\partial M} = 0 = \delta_1 XR_1(1+\beta M(1-R_1)) + \gamma_2 R_1 X\beta(1-R_1-E_1) + M\delta_2 \beta XE_1 R_2(1-R_1-R_2)$$
$$= \gamma_3 X\beta[R_1(1-R_1) - R_1R_2E_1 + E_1R_2(1-R_2)] - \lambda X[\Theta_2 \beta R_1(1-R_1-E_1)$$
$$+ \Theta_3 \beta[R_1(1-R_1) + E_1R_2(1-R_2) - R_1E_1R_2]$$

$$(3) \quad \frac{\partial L}{\partial \lambda} = 0 = F - \Theta_1 X - \Theta_2(R_1+E_1)X - \Theta_3(R_1+E_1R_2)X.$$

Solving (1) for λ, substituting into (2) and simplifying, we arrive at the following which implicitly defines M, the optimal bonus level.

$$
\begin{aligned}
(4) \quad 0 = {} & [\delta_1 R_1 + \delta_2 R_2 E_1][\Theta_1 + \Theta_2(R_1 + E_1) + \Theta_3(R_1 + E_1 R_2)] + \\
& \delta_1 M\beta R_1 [\Theta_1(1-R_1) + \Theta_2 E_1 + \Theta_3 E_1 R_2^{\,2}] + \\
& \delta_2 M\beta E_1 R_2 [\Theta_1(1-R_1-R_2) + \Theta_2(E_1 - E_1 R_2 - R_1 R_2) - \Theta_3 R_1 R_2] - \\
& \gamma_1 \beta [\Theta_2 R_1(1-R_1-E_1) + \Theta_3(R_1(1-R_1) + E_1 R_2(1-R_1-R_2))] + \\
& \gamma_2 \beta [\Theta_1 R_1(1-R_1-E_1) + \Theta_3 E_1(R_1 + E_1 R_2 - E_1 R_2^{\,2} - R_1 R_2^{\,2})] + \\
& \gamma_3 \beta [\Theta_1 \{R_1(1-R_1) + E_1 R_2(1-R_1-R_2)\} + \Theta_2 \{R_1 E_1 + E_1 R_2(E_1 - E_1 R_2 - R_1 R_2)\}]
\end{aligned}
$$

Once M is determined we used (3) to determine X, the required number of eligibles.

APPENDIX C

EQUATIONS TO CALCULATE MODEL PARAMETERS

First term costs are defined as:

$$\gamma_1 = [(REC\$+PROC\$)(1-RTCS(1-ASCHS)STAYER) + RTC\$(1-(1-ASCHS)STAYER)RTCS + ASCH\$(RTCS)ASCHS + TERM\$1(1-\frac{DAYS+56}{365})(RTCS)ASCHS + TERM\$2(RTCS)(ASCHS)TERMS1 + TERM\$3(RTCS)(ASCHS)(TERMS1)TERMS2 + TERM\$4(RTCS)(ASCHS)(TERMS1)(TERMS2)(TERMS3)] / [(RTCS)(ASCHS)(TERMS1)(TERMS2)(TERMS3)(ELIG)]$$

where

REC$ = Marginal recruiting costs

PROC$ = AFEES processing costs

RTC$ = Recruit training costs

ASCH$ = A-school training costs

TERM$1 = First year RMC

TERM$2 = Second year RMC

TERM$3 = Third year RMC

TERM$4 = Fourth year RMC

RTCS = Recruit training survival rate

ASCHS = A-school training survival rate

DAYS = Days spent in A-school training

STAYER = Proportion of A-school failures who remain in the Navy

TERMS1 = Survival rate from the end of A-school until year 2

TERMS2 = Survival rate from year 2 to year 3

TERMS3 = Survival rate from year 3 to year 4

ELIG = Eligibility rate for reenlistment.

Second year costs are defined as:

$$\gamma_2 = \text{TERM\$5} + \text{TERM\$6}(\text{TERMS5}) + \text{TERM\$7}(\text{TERMS5})(\text{TERMS6}) + \text{TERM\$8}(\text{TERMS5})(\text{TERMS6})(\text{TERMS7})$$

where

TERM$5 = Fifth year RMC

TERM$6 = Sixth year RMC

TERM$7 = Seventh year RMC

TERM$8 = Eighth year RMC

TERMS5 = Survival rate from year 5 to year 6

TERMS6 = Survival rate from year 6 to year 7

TERMS7 = Survival rate from year 7 to year 8.

In both cost equations, all costs are expressed in present discounted value.

First term productivity is defined as:

$$\Theta_1 = (E_1 + E_2 TERMS_1 + E_3(TERMS1)TERMS2 + E_4(TERMS1)(TERMS2)(TERMS3))/((TERMS1)(TERMS2)(TERMS3)ELIG)$$

where

E_1 = productivity from the end of A-school until the end of year 1

E_2 = productivity in year 2

E_3 = productivity in year 3

E_4 = productivity in year 4.

Second term productivity is defined as:

$$\Theta_2 = E_5 + E_6 TERMS5 + E_7(TERMS5)(TERMS6) + E_8(TERMS5)(TERMS6)(TERMS7)$$

where

E_5 = productivity in year 5

E_6 = productivity in year 6

E_7 = productivity in year 7

E_8 = productivity in year 8.

In both productivity equations, we implicitly assume that during the time they dc serve individuals who eventually attrite are as productive as the average individual.

APPENDIX D

BASIC DATA

Rating	A-school survival rate	A-school costs	Days spent in A-school	% of A-school failures who remain in the Navy
1	.84	$6046	71	.97
2	.96	3186	49	.91
3	.81	7435	113	.92
4	.91	6132	60	.88
5	.41	18084	240	.93
6	.89	3921	65	.86
7	.61	10863	151	.92
8	.86	6763	70	.92

Rating	Number of reenlistment eligibles	Coefficient of responsiveness of reenlistments to pay	Average length of extension (months)
1	1652	.000222	13.4
2	2743	.000272	14.8
3	1082	.000144	7.2
4	1577	.000144	6.1
5	176	.000198	17.2
6	3187	.000194	15.2
7	1356	.000194	11.7
8	1199	.000148	12.2

Rating	RMC for year 5	RMC for year 6	RMC for year 7	RMC for year 8
1	$10273	$10406	$10476	$10530
2	10271	10376	10446	10497
3	10202	10400	10463	10500
4	10190	10369	10474	10516
5	10128	10276	10386	10445
6	10321	10405	10478	10545
7	10226	10370	10442	10529
8	10227	10381	10388	10522

The following parameters were found to not be significantly different across rating groups or could not be defined at the rating level.

AFEES processing cost	$179
Recruiting training survival rate	.88
Recruit training cost	$2815
Rate of eligibility for reenlistment	.92
RMC for year 1	$9744
RMC for year 2	$9811
RMC for year 3	$9898
RMC for year 4	$9999
Continuation rate from the end of A-school to the start of year 2	.95
Continuation rate from year 2 to year 3	.95
Continuation rate from year 3 to year 4	.95
Continuation rate from year 5 to year 6	.97
Continuation rate from year 6 to year 7	.97
Continuation rate from year 7 to year 8	.97

APPENDIX E

SPECIFICATION OF THE REENLISTMENT DECISION EQUATIONS

We use CNA's Annualized Cost of Leaving Model to project the impact of changes in bonus policy on the reenlistment decision. Information about the assumptions involved in using our specification and the data source for each parameter can be found in the calculation of parameters section of this paper.

In the simple model, we specify the equation to predict the reenlistment rate as

$$(1) \quad R = \frac{e^{\alpha_R + \beta(RMC+M)}}{1 + e^{\alpha_R + \beta(RMC+M)}}$$

where

R = the reenlistment rate

β = the responsiveness of the reenlistment rate to pay changes

RMC = regular military compensation

M = the annualized value of the bonus payment

and α_R = the intercept coefficient based on the base reenlistment rate.

In the model with extenders, we specify the following equations to predict the initial reenlistment and extension rates.

(2) $$R = \frac{e^{\alpha_R + \beta(RMC+M)}}{1 + D}$$

(3) $$E = \frac{e^{\alpha_E + \beta(RMC)}}{1 + D}$$

here

E = the extension rate

α_E = the intercept coefficient based on the base extension rate

D = the sum of the two numerators

nd the other variables are as defined above.

We use equation (1) with the appropriate α_R to project the eenlistment rate of those who initially extend.

APPENDIX F

FORCE STRUCTURE AND SIZE UNDER ALTERNATIVE POLICIES

Simple Model - Optimal Policies with No Recruiting Cost

Rating	Current reenlistment rate	Current personnel yrs 1-8	Optimal reenlistment rate	Optimal personnel years 1-8 effectiveness constrained	Optimal personnel years 1-8 costs constrained
1	.13	10356	.48	9115	9972
2	.22	15960	.58	13976	15236
3	.14	7070	.40	6098	6541
4	.26	10012	.42	9231	9454
5	.23	2457	.66	1914	2241
6	.17	19502	.49	16859	18394
7	.17	12038	.60	9414	11102
8	.16	7450	.44	6384	6961

Simple Model - Optimal Policies with Current Recruiting Costs

Rating	Current reenlistment rate	Current personnel yrs 1-8	Optimal reenlistment rate	Optimal personnel years 1-8 effectiveness constrained	Optimal personnel years 1-8 costs constrained
1	.13	10356	.54	8961	10105
2	.22	15960	.64	13762	15454
3	.14	7070	.47	5921	6562
4	.26	10012	.48	9016	9395
5	.23	2457	.71	1883	2283
6	.17	19502	.55	16520	18587
7	.17	12038	.65	9244	11306
8	.16	7450	.50	6244	7007

Model with Extenders - Optimal Policies with No Recruiting Cost

Rating	Current reenlistment rate plus extension rate	Current personnel yrs 1-8	Optimal initial reenlistment plus extension rate	Optimal personnel years 1-8 effectiveness constrained	Optimal personnel years 1-8 costs constrained
1	.34	11165	.54	9891	10559
2	.30	16398	.60	14375	15522
3	.23	7134	.44	6194	6616
4	.30	10028	.45	9241	9466
5	.35	2556	.67	2042	2308
6	.32	20435	.53	17916	19184
7	.30	12256	.63	9794	11283
8	.33	7930	.51	6872	7342

Model with Extenders - Optimal Policies with Current Recruiting Costs

Rating	Current initial reenlistment plus extension rate	Current personnel yrs 1-8	Optimal initial reenlistment plus extension rate	Optimal personnel years 1-8 effectiveness constrained	Optimal personnel years 1-8 costs constrained
1	.34	11165	.59	9675	10594
2	.30	16398	.66	14125	15684
3	.23	7134	.51	5990	6604
4	.30	10028	.50	9008	9390
5	.35	2556	.71	2002	2337
6	.32	20435	.59	17485	19234
7	.30	12256	.67	9616	11464
8	.33	7930	.56	6692	7329

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